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PACIFIC N. W. FOREST AND RANGE EXPERIMENT STATION

Progress Report

STUDIES OF THE BIOLOGY AND CONTROL OF THE BALSAM WOOLLY APHID IN OREGON AND WASHINGTON
1958 SEASON

By

R. G. Mitchell, Entomologist
Division of Forest Insect Research

Pacific Northwest Forest and Range Experiment Station
U. S. Forest Service
Portland, Oregon
April 1, 1959

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SUMMARY

In 1957 the Pacific Northwest Forest and Range Experiment Station joined with Oregon State College in a two-year cooperative study to explore the possibilities of biological control of the balsam woolly aphid (*Chermes piceae* Ratz.). This report presents the results of the second season's work by the cooperators.

Six foreign insect predators of the balsam woolly aphid were released in 1958 at various points in Oregon and Washington. Five of the species were from Europe, and one from Japan. Of the European species, the coleopteron *Laricobius erichsonii* and the dipteron *Aphidoletes thompsoni* are at least temporarily established. The Japanese species *Chilocorus kuwanae*, a coleopteron, was not successfully established.

An investigation of the native predators affecting *Chermes* in the Pacific Northwest revealed eight insect species and one mite that are definitely predaceous on the balsam woolly aphid. Five of the insects were dipterons and the other three belonged to the order Neuroptera. The most important predators were three syrphids -- *Cnemodon rita* Curran, *Syrphus vitripennis* Mg., and *Syrphus opinator* O.S. Descriptions of the most important species and some information on their life history and behavior were recorded. In addition to the known predators, 13 other species of arthropods which may be predaceous on the balsam woolly aphid were collected.

An attempt was made in the Black Rock area of western Oregon to numerically evaluate the effectiveness of native predators in controlling *Chermes piceae*. The attempt at evaluation largely failed, but valuable information was gained on techniques which should improve future assessments.

Observations on apparent susceptibility and nature of gouting on subalpine fir revealed that as few as seven crawlers settling on the new growth in late summer will cause bud inhibition of this host species. Populations of more than sixteen will result in complete kill of the distal portion of the twig. These results suggest that the most severe symptoms of gout in subalpine fir are caused by prolonged, light infestations.

Chermes-damaged trees on three trend plots in Pacific silver fir stands near Mount St. Helens, Washington, showed improvement in 1958. The largest trees continued to exhibit the greatest damage and to be the slowest to recover. Although the improvement in these stands has been considerable over the past few years, tree killing in other areas continues to be high.

INTRODUCTION

In 1954, the balsam woolly aphid (Chermes piceae Ratz.) was discovered in epidemic proportions near Mount St. Helens in Washington. Since that time more than 600,000 acres of true fir, Abies spp., in both Oregon and Washington have been infested. Damage to Pacific silver fir, Abies amabilis (Dougl.) Forbes, has been especially serious. Although there have been localized fluctuations in the insect population and tree damage, the region-wide trend has been upward. Aphid populations in 1958 were at least as high in most areas as they were when the outbreak was discovered.

In an attempt to develop control measures for this pest, the Pacific Northwest Forest and Range Experiment Station joined with Oregon State College in 1957 in a two-year cooperative program to explore the possibilities of biological control. The purpose of the following report is to describe the procedures, observations, and results of the second season's work by the cooperators. Results of the first year's work have been reported.1/

Those concerned with the conduct of the project to date in addition to the writer are: Dr. J. A. Rudinsky, Project Leader representing Oregon State College; K. H. Wright, Project Leader representing the Experiment Station; P. E. Buffam, field assistant; and John Neeley, laboratory assistant. Acknowledgment is also made to entomologist N. E. Johnson of the Weyerhaeuser Forestry Research Center at Centralia, Washington, who has cooperated on the susceptibility studies and other phases of the work.

1/ Studies of the Biology and Control of the Balsam Woolly Aphid, 1957 season, by R. G. Mitchell. Progress Report. Pacific Northwest Forest and Range Experiment Station. February 15, 1958. Portland, Oregon.

STUDY OBJECTIVES

The broad objective of the cooperative project is to develop a biological control program for the balsam woolly aphid. To achieve this objective investigations are necessary in two areas of study: (1) the biology and behavior of *C. piceae*, and (2) the biology and effectiveness of introduced and native predators.

As in 1957, secondary objectives were assigned to guide the season's work. They were as follows:

1. Introduce and colonize foreign predators of the balsam woolly aphid.
2. Determine if the introduced predators are successful in initial establishment; if so, how much and when the host is affected.
3. Obtain and identify as many as possible of the native predators that prey on chermes[1] populations in the Pacific Northwest.
4. Study the life history and habits of at least the more common native predators.
5. Study the possibilities of mass collecting, rearing and colonization of the more important native predators.
6. Make observations on the general distribution and trend of chermes infestations in Oregon and Washington.
7. Determine the native and exotic species of *Abies* now infested with chermes, and the nature of susceptibility.
8. Examine and evaluate chermes damage on permanent trend plots in Pacific silver fir stands.

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[1] Hereafter in the report the generic name *Chermes* is not capitalized and underlined if it is used as a common name.

INTRODUCTION OF FOREIGN PREDATORS

In 1957, plans for importing foreign predators of the balsam woolly aphid to northwestern United States were made between Science Service, Canada Department of Agriculture, and the Forest Service, U. S. Department of Agriculture. This portion of the report summarizes progress on predator importations in 1958. For more detailed information, reference is made to a special report on this project.[1]

Introductions in 1958

A significant start was given the predator introduction program in 1957 with the release of some 1800 adults of the European predator *Aphidoletes thompsoni* Mohn. (Diptera: Itonididae). Results of the 1957 releases have been reported.[2] This year, five other species, as well as *Aphidoletes*, were released at various points in Oregon and Washington. Table 1 summarizes the introductions and colonizations.

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[1] Colonization of Foreign Insect Predators in 1958 for Control of the Balsam Woolly Aphid. Progress Report. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. March 15, 1959.

[2] Colonization in Oregon and Washington of *Aphidoletes thompsoni* - An European predator of the balsam woolly aphid by K. H. Wright and R. G. Mitchell. Progress Report. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. Feb. 1, 1958.

Table 1.--Summary of predator releases in Oregon and Washington, 1958

Species	Source	No. colonized	Release points
Laricobius erichsonii (Coleoptera: Derodontidae)	Czechoslovakia	8,525	Toutle R., Wash. Green R., Wash. Wind R., Wash. Black Rock, Oreg. Corvallis, Oreg. Willamette Pass, Oreg.
Aphidoletes thompsoni (Diptera: Itonididae)	Czechoslovakia	2,480	Benton Lane Park, Near Monroe, Oreg.
Aphidecta obliterata (Coleoptera: Coccinellidae)	Sweden	720	Green R., Wash. Corvallis, Oreg.
Neoleucopis obscura (Diptera: Chamaemyiidae)	Maine (Europe)	700	Green R., Wash.
Cremifania nigrocellulata (Diptera: Chamaemyiidae)	Czechoslovakia	385	Willamette Pass, Oreg.
Chilocorus kuwanae (Coleoptera: Coccinellidae)	Japan	135	Green R., Wash. Corvallis, Oreg.
Total		12,945	

Results of Colonizations

Aphidoletes larvae were found in fair abundance on the release tree in Benton-Lane park 17 days after the first release. Two weeks later they were very scarce, suggesting that the extremely dry summer took its toll. However, one larva was found in mid-September, after some good rains, suggesting that the colony may have survived.

Aphidoletes larvae were also found on one 1957 release tree in the Green River drainage in Washington. The predators were abundant throughout August and early September but became scarce after the beginning of fall rains. About 40 adults were reared in the laboratory from hand-picked larvae. It was encouraging that no parasitism was noted in the rearings.

Two larvae believed to be Cremifania nigrocellulata were found on the Willamette Pass release tree on August 12. Both specimens agreed in all respects with the published descriptions by Brown and Clark.[1] No larvae or pupae were found after that date.

Progeny of Laricobius erichsonii were found at all release points except those at Toutle River and Wind River. Predation on the chermes populations became apparent soon after appearance of the Laricobius larvae.

Eggs believed to be those of Aphidecta obliterata were found on the release tree at Green River, Washington, but no larvae were recovered. No evidence of establishment by Neoleucopis obscura or Chilocorus kuwanae was found.

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[1] Brown, N. R. and R. C. Clark. 1956. Studies of the Predators of the Balsam Woolly Aphid, Adelges piceae (Ratz.) (Homoptera: Adelgidae) I. Field Identification of Neoleucopis obscura (Hal.), Leucopina americana (Mall.) and Cremifania nigrocellulata Cz. (Diptera:Chamaemyiidae). Can. Ent. 88(6):272-9.

IDENTIFICATION AND STUDY OF NATIVE PREDATORS

Work in 1958 was largely an expansion of that started in 1957. Because investigations did not start until mid-July that year, creating the possibility that an entire spring complex of predators was missed, one of the main purposes of this year's work was to determine what species are present in the spring. It was also hoped that improved techniques would reveal possible predators overlooked during the latter part of 1957.

Methods and Procedures of Study

With one exception, collections were made in the same areas and on the same tree species as in 1957. The one addition was a farm woodlot adjacent to Benton-Lane Park, near Monroe, Oregon. Table 2 presents the general locations of the trees, the species represented, and the approximate elevations of the study areas.

Table 2.--Elevation, location, and tree species studied at predator collection areas.

Location	Tree species	Elevation
Toutle and Green River Drainages, Wash.	*A. amabilis*	2500 - 3500
Wind River Arboretum, Wash.	*A. alba* and *A. lasiocarpa*	1000
Black Rock, Oreg. (Upper Warnick Creek Drainage)	*A. amabilis*	2800
Corvallis, Oreg.	*A. grandis*	230
Benton-Lane Park, Oreg. (Near Monroe, Oreg.)	*A. grandis*	350
Willamette Pass, Oreg.	*A. lasiocarpa*	4000

Each area except the Toutle and Green River drainages was examined for predators at least twice during the months of March, April, and May. After mid-June and until the last of September, all areas were checked at least every other week.

Rearings to obtain adults, most of which were dipterons, proceeded in much the same manner as in 1957.[1] Small plastic cages were used in the field to isolate individual predators on the trees. For those insects that pupate in the soil, small trays were devised to catch the larvae as they dropped from the trees. Two species of syrphids were found that would neither pupate when caged on the tree nor drop into trays. In this case puparia could be obtained only by hand picking mature larvae and rearing them in wet sand.

After pupation, predators were placed in a moderately moist environment until adults emerged. Large species were usually reared on soil in 4-inch shell vials. Small species were reared more easily in gelatine capsules.

One problem encountered was that of detecting very small predator species and then determining whether or not the species or stage was predaceous on chermes. Adapting a binocular microscope to fit on an elevator-type camera tripod solved the problem in part. This apparatus allows the observer to minutely cover about 90 square inches of bark surface without moving the tripod. More important, both hands are free to handle vials, probes, etc. Both microscope and tripod are light and are easily carried by one man. Chief disadvantages are: (1) a great deal of time is required to cover a relatively small bark area, and (2) the apparatus can be operated

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1/ Described and illustrated in the 1957 progress report.

only from the ground. The latter shortcoming was overcome by removing the microscope's rack and pinion and replacing it with a metal "dog". The microscope was then suspended by an adjustable strap attached to a limb or a nail driven into the tree (figure 2). This adaptation allows considerable maneuverability. The one disadvantage is that the microscope is somewhat difficult to focus and requires that one hand be used to steady it.

Known and Possible Predators Collected

In 1957 three species of native predators were found definitely feeding on *Chermes piceae*. The same species, plus five more, were seen preying on chermes in 1958. In addition, 13 species of arthropods were found which may be predaceous. A list of the known and possible predators follows:

Known Predators

CLASS INSECTA:

Diptera: Syrphidae - *Cnemodon rita* Curran
Diptera: Syrphidae - *Syrphus vitripennis* Mg.
Diptera: Syrphidae - *Syrphus opinator* O.S.
Diptera: Chamaemyiidae - *Leucopis* sp., near *atrifacies* Ald.
Diptera: Itonididae - Undetermined
Neuroptera: Hemerobiidae - *Hemerobius neadelphus* Gurney
Neuroptera: Chrysopidae - *Chrysopa* sp. plorabunda group
Neuroptera: Chrysopidae - Undetermined trash carrier

CLASS ARACHNIDA, ORDER ACARINA:

Trombidiformes: Anystidae - *Anystis* sp.

Possible Predators

CLASS INSECTA:

Diptera: Syrphidae - *Metasyrphus amalopsis* (O.S.)
Diptera: Syrphidae - *Metasyrphus aberrans* Curran
Diptera: Itonididae - *Lestodiplosis* sp.
Neuroptera: Hemerobiidae - *Hemerobius conjunctus* var. *conjunctus* Fitch
Neuroptera: Raphididae - *Agulla* sp. near *adnixa*
Neuroptera: Chrysopidae - *Chrysopa* sp., plorabunda group
Coleoptera: Coccinellidae - *Mulsantina picta* (Rand.)
Coleoptera: Coccinellidae - *Cycloneda polita* Csy.
Coleoptera: Coccinellidae - Unknown and not reared
Coleoptera: Unknown family

CLASS ARACHNIDA, ORDER ACARINA:

Trombidiformes: Bdellidae - *Biscirus uncinatus* (Krm.)
Trombidiformes: Anystidae - *Anystis agilis* (Banks)
Trombidiformes: Tydeidae - *Tydeus* sp.
Mesostigmata: Phytoseiidae - *Typhlodromus bakeri* (Garmen)

Description and Habits of Known Predators

The following discussion summarizes observations made on the arthropods found to be predaceous on *Chermes piceae*.

Cnemodon rita (Diptera: Syrphidae)

This is the region's most abundant, and possibly most important, native predator of *C. piceae*, and adults have been reared and identified from every collection point and host tree. However, populations were noticeably smaller in 1958 than in 1957, especially in the Willamette Valley. This reduction may have been due to the very dry summer of 1958.

Description of Egg and Larval Stages - The egg is white, elongate-ovoid and, when positioned on the bark, is sculptured dorsally with several conspicuous longitudinal ridges; the ventral surface is smooth. Average length, 0.8 mm.; range, 0.75 to 0.90.

There are three larval instars. The newly hatched larva is transparent, but after feeding becomes a dirty white. In all three instars the body segmentation is obscure and the dorsal vestiture is weak. Only a few lateral two-segmented spines are present and they are not prominant until the third instar. Two inconspicuous lobes are situated laterally on each side of the posterior spiracles. Externally, the first instar is distinguished from the other stages by two widely divergent and completely separated anal spiracles. The length of the mouth-hooks average 0.15 mm.; mean body length, 1.02 mm.; range, 0.75 to 1.29 mm.

The second instar varies in color from dirty white to a light yellow-green. The anal lobes are more conspicuous than those of the first instar. This stage is separated from the others by the fact that the posterior spiracles are widely divergent but fused at the base. The length of the mouth-hooks average 0.31 mm.; mean body length, 2.57 mm.; range 2.03 to 3.17 mm.

The third instar ranges in color from a yellow-green feeding stage to a cryptic, olive-drab prepupal stage. When feeding, the insect's dark mid-gut is usually visable through the integument. The anal lobes are prominant and the posterior spiracles are completely fused and exhibit only a slight divergence distally. The length of the mouth-hooks average 0.53 mm.; mean body length, 6.24 mm.; range, 3.95 to 8.32 mm.

Life history - There appears to be two overlapping generations in the lowlands and one at the higher elevations. Ovipositing females were observed at Corvallis from May 15 to May 30. Although adults were not seen later than May 30, the appearance of unhatched eggs on chermes-infested trees indicated that the oviposition period may last as long as 30 days. Eggs are laid singly on the bark surface, in crevices and tucked in chermes egg masses. The incubation period at room temperature is from three to four days.

The duration of the larval period is unknown. Rearing notes show that under laboratory conditions it takes about 15 days for the larva to form a puparium after dropping from the tree. Apparently this is a diapause stage. The insect is in the pupal stage for about 10 days. As was stated above, eggs were observed being oviposited on May 15 at Corvallis. Fresh eggs were again observed on July 23. No unhatched eggs were observed prior to May 15 nor were any seen after the end of the first flight period in mid-June. This suggests that at least some of the predators will pass through a complete cycle in about 60 days. By subtracting the 29 days that the insects are in larval diapause, pupal and egg stages, it is calculated the larva spends about 30 days actively feeding.

Behavior of Insect - Several females were observed ovipositing on bole-infested grand fir at Corvallis. The following is a description of the actions observed.

The female hovers about one inch from the bark before landing. Ten to thirty seconds may be spent hovering in one place. Immediately after alighting on the bark the terminal abdominal segment is evaginated into a long ovipositor. As the female walks around, the ovipositor is moved back and forth in a searching motion. When a suitable oviposition site is found the insect remains motionless for about five seconds while the egg is being deposited. The two most favorable sites appear to be deep bark crevices and heavy concentrations of chermes wool. The female may continue her search and lay two or three more eggs before leaving the bark. After flying, the insect may again hover nearby and settle for more egg laying, but generally the insect flies and disappears after the initial deposit. One female was observed to land on a branch, go through a cleaning process, and then return to the tree for ovipositing.

Egg laying seems to occur as frequently on the shady side of the tree as on the sunny side. Early spring oviposition was observed only on trees at the edge of stands. Most oviposition was observed on warm days when the temperature was about 70° F., although one female was seen laying eggs when it was raining.

First- and second-instar larvae usually feed completely within the chermes wax mass. The prey stages fed upon by these two instars are not known. Probably the egg stage is the one most frequently attacked. Third instar larvae also like to burrow under wax masses while feeding. Their large size, however, allows fairly easy detection. All stages of the balsam woolly aphid are preyed upon except the settled first instar.

Pupation occurs both in the soil and on the tree. The soil is the most common location although many remain on the tree if there are abundant hiding places such as lichens or bark fissures. *C. rita* drops directly from the tree when it pupates in the soil. This habit allows the use of a tray for easy collection of mature larvae.

Seasonal Occurence of Eggs and Larvae - Following are the periods in which eggs and larvae of *C. rita* were observed on chermes-infested trees:

Willamette Pass ----- mid-July until late September
Corvallis ----- mid-May until mid-October
Black Rock ----- early July until late September
Wind River ----- early June until late September
Toutle River ----- early July until late September

Natural Enemies - The following hymenopterous parasites have been reared from *C. rita*:

Chalcidoidea: Endrytidae - *Syrophophagus smithi* Kam.
Chalcidoidea: Pteromalidae - *Pachyneuron allograptae* Ashm.
Ichneumonidae - *Syrphoctonus* sp.
Ichneumonidae - *Phthorima sp.*

polyembryonic

The chalcids, which are polyembrionic, account for the greatest amount of parasitism. Both species attack the pupal stage. The ichneumonids are larval parasites. *Syrphoctonus* appears to be the more important of the two genera found. In one case, four adults of this genus were reared from a collection of nine *Cnemodon* larvae. Only one case of parasitism by *Phthorima* sp. has been found.

Two cases of predation were observed -- one by an unidentified ant and the other by the syrphid, *Metasyrphus amalopsis*. Predation is believed to be rare.

Discussion - *C. rita* appears on very light as well as heavy infestations. It ranges throughout the entire latitude and elevational range of the balsam woolly aphid in Oregon and Washington. Larvae were also collected feeding on an unknown *Pineus* species near Centralia, Washington.[1]

Although the insect is present throughout most of the summer and at almost any prey density, it is seldom very abundant on any one tree. Its value is further impaired because it appears after the first generation of the host has already reached its peak, and disappears just as the second generation is heaviest.

The possibility of securing large collections of *C. rita* for colonization has been handicapped by the small number occuring at any one time. An attempt to obtain a large number of adults by holding the pupal stage at 50° F. was not successful. Emergence was delayed at that temperature but not long enough. A small test at the end of the season suggested that a temperature near 40° F. would give more satisfactory results.

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[1] Courtesy of Mr. Norman E. Johnson, entomologist, Weyerhaeuser Timber Company, Centralia, Washington.

Syrphus vitripennis (Diptera: Syrphidae)

This insect appears to be the region's second most abundant predator. Because of poor rearing techniques in the early part of the year, adults were not obtained until fall and then from only one collection point. Although this prevented positive identification in other areas, eggs and larvae, believed to be from this species, were found at every collection point.

Description of Eggs and Larval Stages - The eggs are yellowish-white, subcylindrical and conspicuously covered with peg-like projections. Exact egg measurements were not made; length appears to range between 1.0 to 1.5 mm.

There are three larval instars. The first instar is uniformly green and bears nine rows of conspicuously long black setae on the dorsum. The anterior three rows have five setae per row and the remaining six rows exhibit eight. The median pair of setae in the caudal row are slightly offset anteriorly. The posterior spiracles are well separated, slightly raised and somewhat divergent. Mean body length is 1.74 mm.; range, 1.35 to 194 mm.

The second instar is pale sea-green with an orange and black mid-dorsal line extending from the cephalic region to the posterior spiracles. Body vestiture with both second and third instars is obscure with only a few inconspicuous setae present. The anal spiracles are separated and slightly raised. Mean body length is 4.24 mm.; range, 2.91 to 5.41 mm.

The color pattern of the third instar is similar to the second, except that it changes to a pale brown in the prepupal stage. The anal spiracles are fused, raised and quite prominent. Mean body length is 7.83 mm.; range, 5.20 to 9.57 mm.

Life History and Behavior - *S. vitripennis* is multivoline, with at least two generations in the higher elevations. For some reason the insect appeared only in early spring at Corvallis. It appears that the dry summer prevented later emergences. Normally the predator pupates in the soil; however, under dry conditions the larvae go into estivation and will not develop further. It was found in the laboratory that the soil must be quite moist before pupation will occur.

The oviposition period was observed at Willamette Pass to last at least 15 days. Eggs were laid singly and conspicuously on the bark of infested trees. The duration of the larval stages is not known. All larval stages feed from outside the wax masses and prey on all chermes stages except the neosistentes. Since puparia have never been found on the tree, it is believed that pupation occurs only in the soil. Puparia were formed in the laboratory 10 to 17 days after being placed in damp soil. Adults emerged about 10 days later.

Seasonal Occurrence of Eggs and Larvae - Small populations of *S. vitripennis* were observed in early spring at Wind River, Corvallis, and Willamette Pass. At Wind River and Corvallis the insect disappeared at the end of May and was not seen again in 1958. The dry summer in these low elevation areas is believed to have prevented further emergence. At Willamette Pass the spring generation disappeared in late June. A large second generation appeared about mid-August in this area and also at Black Rock and Toutle River. Larvae continued to be observed at Willamette Pass until early November. Late fall observations were not made in the other two areas.

Discussion: Synchronization with the host for maximum effectiveness is very good with this predator. Its chief shortcoming is that it generally occurs in quite small numbers. Another fault is its erratic distribution between trees. Sometimes *S. vitripennis* may be extremely abundant on one tree while on an adjacent tree with similar prey density it may be very scarce.

Parasite information was not obtained due to the inability to obtain pupae in the early part of the season.

Syrphus opinator (Diptera: Syrphidae)

This predator was observed in May in large numbers on several chermes-infested trees near Corvallis. At about the same time, and in the same area, another very similar syrphid, *Metasyrphus aberrans*, was found feeding on *Chermes cooleyi* Gill. on Douglas-fir. A laboratory check revealed that both syrphids would feed readily on either *Chermes* species. Because of their similar appearance and host preferences, it was at first mistakenly assumed that they were the same species. Owing to improper rearing techniques, neither syrphid was reared to the adult stage from collection points other than Corvallis. Thus it is not known whether the two species were also confused in other areas. Based on Heiss'[1] larval descriptions separating the two genera, it appears that *M. aberrans* was not encountered again. Until positive identifications can be made, it will be assumed that the syrphids observed in other localities were *S. opinator*.

Description of Egg and Larvae - The egg is white, subcylindrical and covered with conspicuous longitudinal reticulations. The length of one measured egg was 1.36 mm.

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[1] Heiss, Elizabeth M. 1938. A Classification of the Larvae and Puparia of the Syrphidae of Illinois Exclusive of Aquatic Forms. Univ. of Ill. Bull. #1. Urbana, Illinois.

There appears to be three larval instars. The first and second instars have not been examined in detail. The third instar ranges from 6.5 to 13.0 mm. in length and has yellow, black, and light green markings. Green predominates on the pleural regions and becomes increasing paler cephalad until the head region is a yellowish-cream color. Dorsally the color pattern is broken by black, chevron-shaped patterns. Small yellow areas occur between the black markings. A small spine occurs at each end of five, regularly spaced, transverse, cream-colored projections. The integument is covered with numerous, minute, recurved spines. The anal spiracles are deeply recessed in a triangular shaped pocket. The ventral body surface is characterized by seven pairs of proleg-like projections. Each projection has three lobes.

Life History and Behavior - Apparently most of the population is univoltine, with only a few individuals having two generations. The eggs are laid singly and conspicuously on the bark surface of chermes-infested trees. Duration of the larval period is from 20 to 30 days. It is a very active feeder and preys on all stages of the balsam woolly aphid except the neosisten. Larval searching is entirely random and all the chermids under a wax mass are seldom devoured the first time they are encountered. However, the predator frequently retraces its previous paths and often completely destroys its prey within sizeable areas.

Puparia are easily obtained under laboratory conditions but adults do not emerge readily. Only two have been reared to date. Apparently some critical moisture condition is needed to cause them to break diapause. Pupation usually occurs in the soil, although a few specimens were observed to form puparia on trees. Those that pupate in the soil do not seem to drop directly from the tree to the ground. They could not be caught in trays and none were found by sifting the soil at the base of trees. A larva was once observed crawling on the ground about two feet away from the base of the tree. This suggests a purposeful migration down the stem and away from the tree.

Seasonal Occurrence of Eggs and Larvae - The largest numbers of this predator were observed in the spring when the chermes population was reaching its peak. The following summarizes the periods in which larvae were observed on the trees:

Willamette Pass -- Mid-June to late July, and again in late August.

Corvallis -- Early May to mid-June, and again in mid-August.

Black Rock -- Mid-June to mid-July; larvae were not seen again although adults were collected on August 21.

Wind River -- Only eggs observed in mid-May; next check in mid-June revealed nothing and no larvae were seen thereafter.

Toutle River -- Late June to early August and again in early September.

Natural enemies - The following hymenopterous parasites have been reared from Syrphus opinator:

Chalcidoidea: Pteromalidae - Pachyneuron allograptae Ashm.
Ichneumonidae - Diplazon orbitalis Cress
Ichneumonidae - Syrphoctonus sp. (2 species)

The first two species were reared from insects that pupated on the tree. The chalcids, which are polyembrionic, were collected from three puparia, while the ichneumonid, D. orbitalis, was represented by only one specimen. The two unknown species of Syrphoctonus sp. seem to be the most important parasites. Both attack the larval stage and have been reared from about 15 percent of the predators collected.

Discussion - When abundant, S. opinator is very effective in reducing the prey population. Its chief fault is that it does not exert its greatest effect until the first chermes generation has reached its peak. By then a large number of eggs have already hatched and the sistentes constituting the next generation have already settled.

An observation at Corvallis on the relation of predator number to prey density revealed the following:

Number of prey per square inch	Number of S. opinator per 100 square inches
42.0	5.72
21.0	1.93
7.4	0.21

For some reason this predator was much more abundant at Corvallis than elsewhere. At Willamette Pass and Black Rock the syrphid appeared fairly abundant in the early instars but later became quite scarce. Two possible reasons for the drop in numbers are that birds preyed on them or the predator changed hosts. An unknown species of *Cinara*, common on or true firs, has been observed to be a natural host of *S. opinator*.

Leucopis sp., near *atrifacies* (Diptera: Chamaemiidae)

Adults of this species have been reared from puparia collected at every point except Toutle River. Larval collections have been few and were made only at Corvallis and Black Rock. The egg stage has not been observed.

Mature larvae are from 2.0 to 4.0 mm. long and are creamish-white in color. Chief distinguishing characteristics of the larvae are two widely divergent posterior spiracles.

Pupation usually takes place in bark crevices and under lichen and chermes wool. A collection of several larvae and puparia in a tray at Black Rock suggests that at least some of the larvae pupate in the soil. The species probably does not occur in large numbers; however, because of the small size and pale color of the larva, it is difficult to detect and may have been more abundant than thought.

Two parasitic chalcids were reared from the puparia of this species -- *Pachyneuron* sp. and *Lygocerus* sp.

Undetermined Itonididae (Diptera)

Only a few observations have been made on this predator. Larvae have been collected only from Black Rock and Toutle River. The insect first appeared in late July and was present until late September. Ten larvae represent the largest single collection and they were obtained from a tray attached to the bole.

The larvae are about the same size and color as the introduced itonidid, *Aphidoletes thompsoni*. They differ morphologically in that the native predator has two prominent anal horns. Also, the head capsule and spatula are formed somewhat differently (figure 1). In habits they are much alike. Both feed entirely concealed by chermes wool, and are found only by disturbing them with a probe or removing their cover. Both pupate in the soil and make the same type of pupal chamber from silk and soil particles. Adult females are conspicuously different. The unknown itonidid is densely pubescent with dark hairs. The wings have the same venation but differ markedly in the amount and color of vestiture -- the unknown species having so many dark hairs that the wings appear mottled.

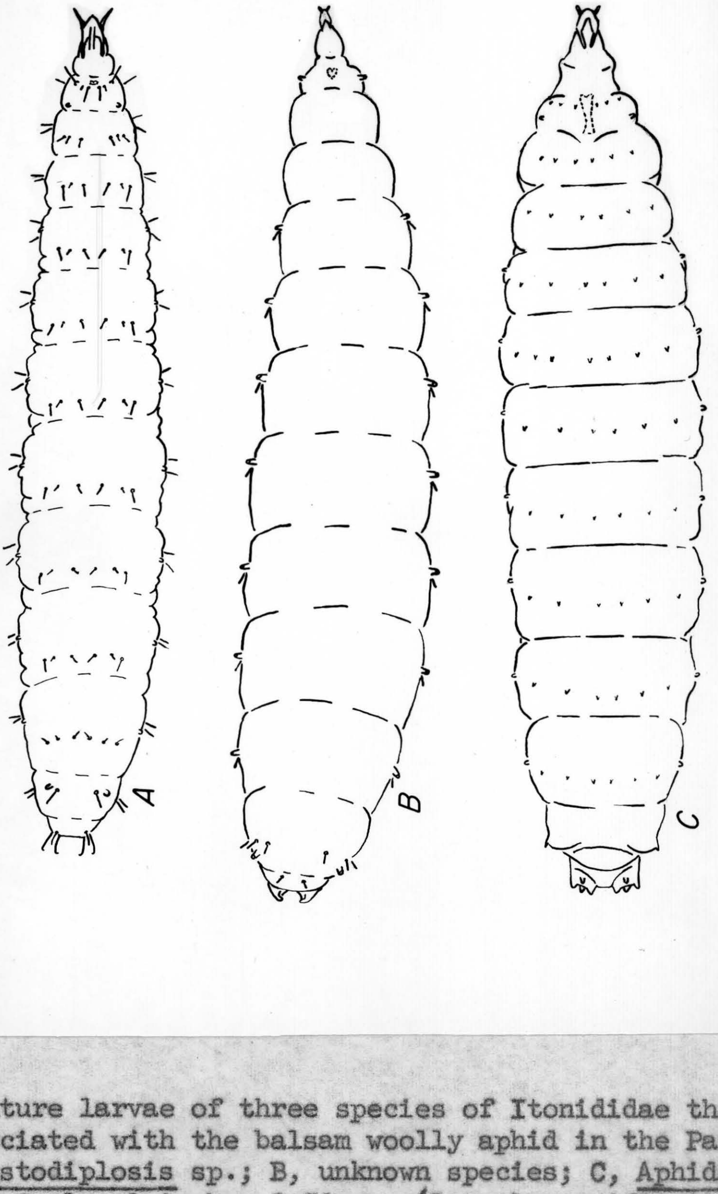

Figure 1.--Mature larvae of three species of Itonididae that prey on or are associated with the balsam woolly aphid in the Pacific Northwest: A, *Lestodiplosis* sp.; B, unknown species; C, *Aphidoletes thompsoni*. Scale: 1 inch = 0.53 mm. (Larval magnification - 48 X)

Hemerobius neadelphus (Neuroptera: Chrysopidae)

This neuropteron was found only at Willamette Pass. It was observed from mid-June until mid-October. Larvae never appeared in great abundance and they seemed to exert little influence on the chermes population. They are quite erratic in feeding, doing considerable wandering before selecting a chermid. Pupation apparently takes place in the soil, although mature larvae will readily pupate when caged on the tree. Eggs have never been found on the tree, suggesting that a different insect may be the primary host.

The distinguishing characteristic of the larva is its color, which is dark brown with longitudinal white lines on the head and thorax. The last five abdominal segments are pink.

One larval parasite, *Anacharis punctatifrons* Kieffer (Cynipoidea: Anacharidae), was reared from this neuropteron. *Metasyrphus amalopsis* readily attacks the larval stage. This syrphid appears to be the predator's chief insect enemy.

Chrysopa sp. plorabunda group (Neuroptera: Chrysopidae)

Only one larva was collected. This was from Wind River in early July. It was feeding on chermes when collected and pupated before it could be described or photographed. Nothing else is known about the insect.

Unknown Chrysopid Trash Carrier (Neuroptera)

Larvae of this species were observed only a few times, in early August at Corvallis and at Benton-Lane Park. This very interesting insect piles chermes wool, sistens, and eggs on its back. In the early instars it appears very much like a moving chermes wax mass. Strangely, the insect had been found only on one tree in each of the study areas. A maximum of four larvae were found per tree. The insect pupated readily when caged on the tree, but pupae would not produce adults under laboratory conditions.

Anystis sp. (Trombidiformes: Anystidae)

This mite was observed feeding on chermes at Corvallis in early May. Although hundreds of mites were seen, positive predation was observed only once. Primary predation by *Anystis* was probably confined to a phytophagous mite, *Brevipalpus* sp., which was abundant on the trees at the same time.

Notes on Possible Predators

None of the following arthropods have been observed feeding on the balsam woolly aphid. The possibility of their being predators is suggested by the fact that all were found in association with *C. piceae* and that all belong to groups known to be predaceous on insects.

Metasyrphus amalopsis (Diptera: Syrphidae)

This insect was seldom encountered. Two larvae were collected from a chermes infested grand fir at Corvallis in January. Both formed puparia but only one adult was obtained. One larva was collected in August, 1957, at Willamette Pass and a few more were collected about the same time in 1958. The larvae are very quiescent and are always found attached firmly to the bark by their anal ends.

It is quite possible this insect does not prey on chermes. Observations strongly suggest that it feeds on primary predators. Several times it was found preying on Hemerobius neadelphus and once it was seen feeding on the previously discussed syrphid, Cnemodon rita. However, Cnemodon apparently is not the preferred diet, since attempts to use this species as prey material in the laboratory failed.

Mature larvae are large, 9 to 11 mm. long, and quite striking in color and form. They are colored in various shades of pink, blue, green and black. Numerous long and conspicuous spines complete their unique appearance.

Metasyrphus aberrans (Diptera: Syrphidae)

This syrphid was observed feeding on Chermes cooleyi near Corvallis. However, it was found that in the laboratory it will readily attack C. piceae when presented the opportunity. As previously mentioned, because of the great similarity between the eggs and larvae of M. aberrans and those of Syrphus opinator, and because both species appeared almost simultaneously in May on their different hosts, they were first believed to be the same species. The error was discovered when the adults were later identified at the U. S. National Museum.

M. aberrans was not reared from any locality other than Corvallis.

Lestodiplosis sp. (Diptera: Itonididae)

No adults of this species were obtained, although the larvae are quite easily identified from description given by Peterson.[1] The larvae were found in association with C. piceae at Green River, Washington, and were quite rare; only four specimens were collected. The larva is distinct and easily separated from the introduced Aphidoletes thompsoni and the previously discussed unknown native itonidid. The most distinct features of the immature stage are the nine pairs of proleg-like projections on the ventral surface. Also conspicuous are numerous dorsal, lateral, and anal setae (figure 1). The genus has a reputation for preying on species of the genus Phylloxera, a group closely related to Chermes.

Hemerobius conjunctus var. conjunctus (Neuroptera: Hemerobiidae)

One specimen was reared from a pupa found on the bark of a chermes-infested tree in June, 1957, at the Toutle River study area. The species has not been collected again and nothing further is known about it.

Agulla sp. near adnixa (Neuroptera: Rhaphidiidae)

One adult of this species was collected in 1957 in association with C. piceae at Willamette Pass. In 1958, several snake fly larvae were found but none were observed feeding naturally, nor could they be forced to feed on chermes after starvation. Consequently, none of the larvae were reared, precluding association of them with the adult collected in 1957.

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[1] Peterson, Alvah. 1951. Larvae of Insects; Part II. Edwards Brothers Inc. Ann Arbor, Michigan. 416 pp.

Chrysopa sp. plorabunda group (Neuroptera: Chrysopidae)

Two pupae in this group were found associated with *C. piceae* in 1957 but no adults were obtained. One was taken at Corvallis and the other at Willamette Pass. It was mentioned in the section on known predators that a chrysopid in the plorabund group was observed in 1958 feeding on the balsam woolly aphid. It is not known if it belongs to the same species as the two specimens collected in 1957.

Unknown Coccinellidae (Coleoptera)

Larvae were occasionally found associated with chermes at Corvallis in late May and throughout June. Feeding was not observed. Pupae were collected from the trees in the first week of July, but they failed to produce adults when brought to the laboratory. It is believed they were killed by heat in transit between Corvallis and Portland.

Mulsantina picta (Coleoptera: Coccinellidae)

Two adults were found near Corvallis resting on the bark of chermes-infested grand fir. Neither were observed feeding. One was collected on May 14 and the other on July 23. The latter specimen was a teneral adult and may have been the newly emerged mature stage of the above unknown coccinellid.

Cycloneda polita (Coleoptera: Coccinellidae)

Two adults were found associated with *C. piceae*. One was collected in May at Corvallis and the other in June at Wind River. Both appeared to be merely resting on the bark of infested trees and neither was observed feeding.

Unknown Coleoptera

Several larvae were found on a chermes-infested tree in the Green River drainage. They were quite small, 1 to 2 mm. long, and appeared to belong to either the family Tenebrionidae or Elateridae. Larvae were never seen feeding, and attempts to rear them failed.

Biscirus uncinatus (Trombidiformes: Bdellidae)

This mite was found asociated with C. piceae at Corvallis from late January to mid-April. Although the species had ample opportunity to prey upon chermes, close observation failed to detect it doing so. It is possible that it was feeding on the phytophagus mite, Brevipalpus sp., which was abundant during the same period.

Anystis agilis (Trombidiformes: Anystidae)

For two years this mite has been observed in great abundance on chermes-infested trees at Black Rock. On both occasions they were seen during a short period in late July. At neither time were they observed feeding.

Tydeus sp. (Trombidiformes: Tydeidae) and Typhlodromus bakeri (Mesostigmata: Phytoseiidae)

Both mites were found in late December, 1957, at Black Rock. They were not observed feeding and no other collections of the species have been made since that time.

EVALUATION OF NATIVE PREDATORS

In the previous section some qualitative estimates were made on the efficiency of the identified and more abundant predators. The following section describes the procedures and results of an attempt at quantitative evaluation -- an attempt which largely failed, due to reasons discussed later.

Methods and Procedures of Evaluation

The method used for evaluation of predator effectiveness was a modification of the system designed by N. R. Brown and R. S. Clark at the Fredericton, New Brunswick, Forest Biology Laboratory. On each of five study trees, a five-foot trunk section was marked off, beginning just above ground level, as a sampling area. The number, stage and species of predators were recorded over the entire five-foot area. Prey populations were tallied on 20 one-inch "sub-plots" within the area. These 20 plots were divided into four verticle al rows of five each, located one foot apart on each of the four cardinal sides of the tree. A variation from the method used by Brown and Clark was to protect five of the one-inch plots from predation. This was done by the use of small screen cages (figure 2).

A metal template or "window" hung from two nails was used to delineate the one-inch square sampling units. Recording the population within these plots was aided by the use of a microscope attached either to an elevator-type camera tripod or suspended from the tree by an adjustable strap (figure 2). Counts of the predator population were made by unaided eye or with an ordinary reading glass. Records were kept on a standardized form.

From this sampling scheme the predator population was calculated as to the number of larvae per 1000 square inches of bark surface and prey populations were computed on the basis of "acceptable" sistens (2nd, 3rd, 4th instar) per square inch. The trend of the two populations were then followed by plotting them on graph paper. From these plottings, comparisons could be made between the protected and unprotected prey densities and the predator population.

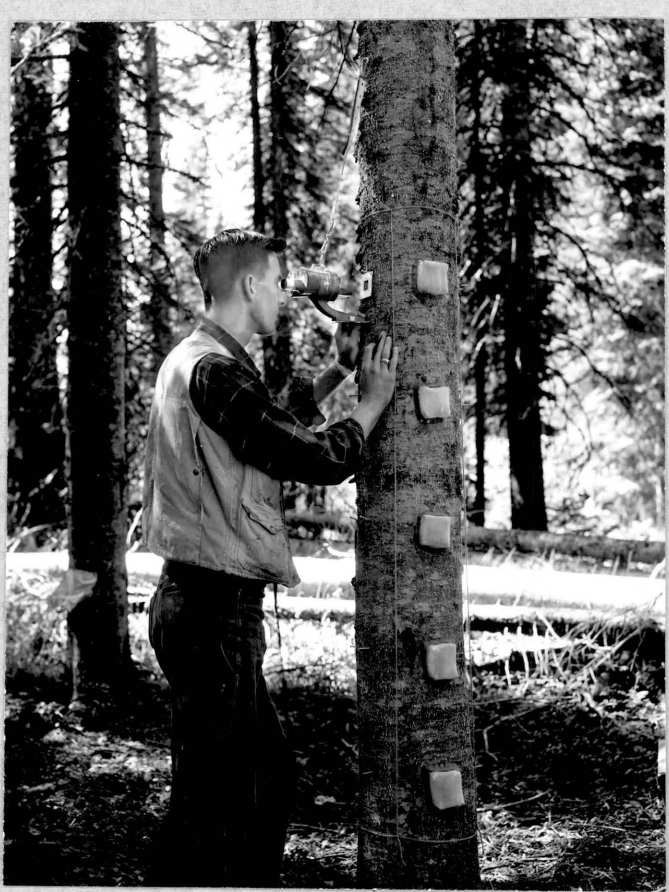


Figure 2.--Evaluating effects of predation. Permanent plots open to predation are being examined with a microscope suspended from the tree by an adjustable strap. The small screen cages exclude predation from check plots.

Five trees representing three species and four areas were selected for sampling. The areas and tree species represented were: (1) Green River, one silver fir; (2) Black Rock, two silver firs; (3) Corvallis, one grand fir; and (4) Willamette Pass, one subalpine fir. An important selection requirement was that the trees have chermes-infestations extending close to the ground. An attempt was also made to pick trees that would survive the summer. At Corvallis a requisite for the tree selected was that it be secluded from the curious public.

Results of Evaluation

As previously mentioned, results of the first year of study were generally disappointing. This was due to: (1) predator populations were low in all areas except Willamette Pass; (2) the plots were installed too late to evaluate the spring complement of predators; and (3) the plot trees at Willamette Pass and Green River were killed during the season, one by bark beetles and the other by chermes. In addition to the loss of these two trees, the Corvallis plot had to be discontinued due to the heavy work load and lack of predators in that area.

Studies on the remaining two trees at Black Rock were maintained even though predators were very scarce. One tree produced only three predator larvae the entire summer. Results of studies on the Black Rock trees (study trees 3 and 5) are presented in figure 3.

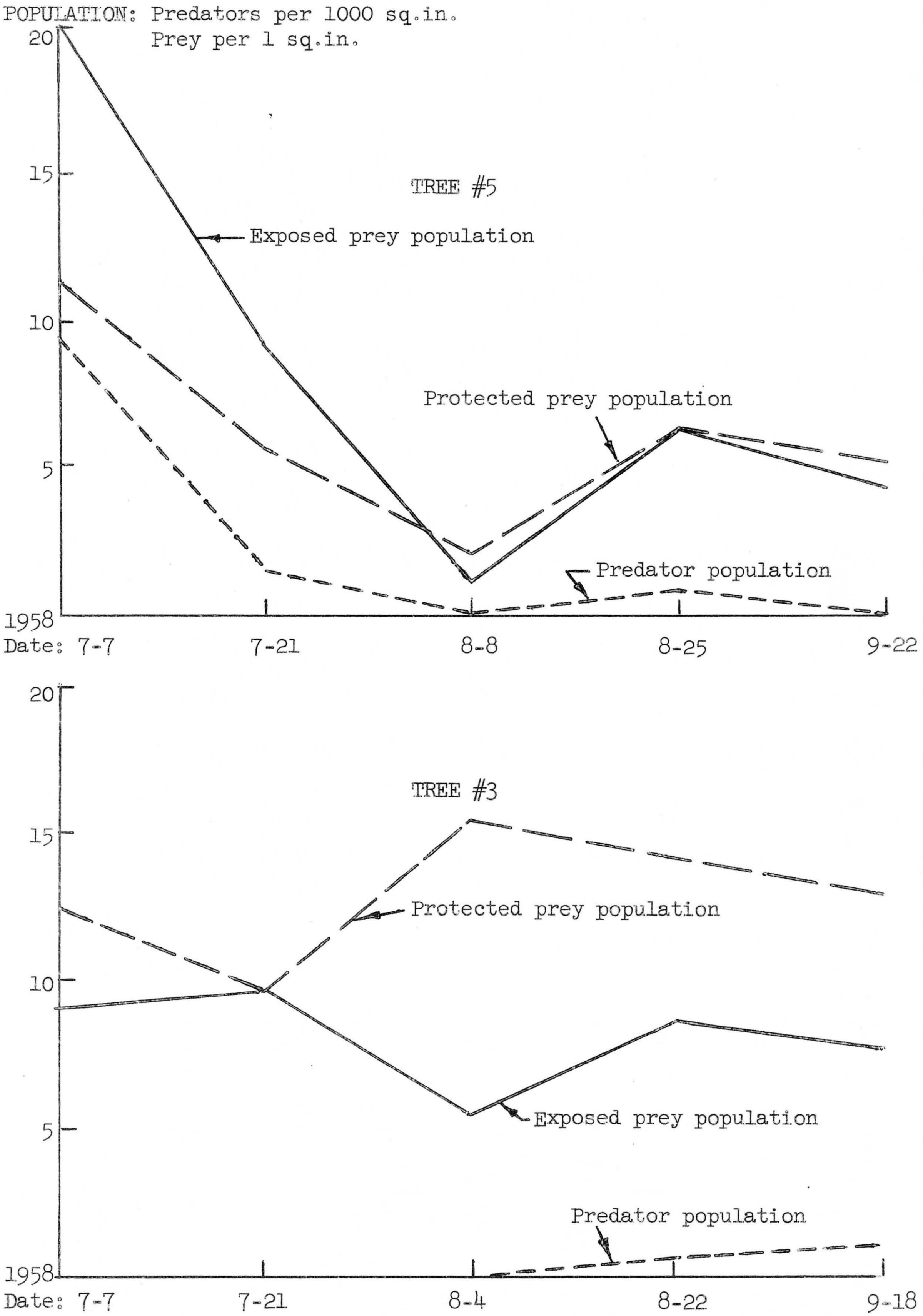


Figure 3.--Evaluation of native predators on two silver firs at Black Rock, Oregon.

The first observation on tree number 5 revealed that the plot was installed too late to catch the peak predator population. At the time of installation there were 13 predators present -- seven *Syrphus opinator* and six *Cnemodon rita*. By July 21, all *S. opinator* had disappeared and the population dropped to two *C. rita* larvae. By August 8 no predators were present. During this decline in predator numbers there was also a sharp decrease in the protected and nonprotected prey densities. This decline appeared to be the natural drop between the peaks of the two aphid generations. There was, however, a differential decline between the protected and non-protected populations. The unprotected population dropped 95 percent from its maximum density while the protected fell only 82 percent. This variation in decrease probably represents the effects of predation, although the test would have been stronger had the plot been installed earlier. Only one predator was seen after August 8, which probably accounts for the two prey densities remaining about equal after that date.

On tree number 3, the protected prey density climbed considerably above the non-protected density even though few predators were observed. The reasons for the odd population patterns are not completely understood. One disrupting factor may have been that the aphids under the cages experienced a materially different environment from those on the rest of the tree. This tree was exposed to direct sunlight during most of the day whereas tree number 5 was usually shaded. Higher temperatures within the cages could have increased insect fecundity and instar development. Records show that egg production on the caged plots was considerably higher than on the rest of the tree.

Another reason for the varied populations could have been that more predation occurred than was indicated by the predator counts. One Leucopis sp. puparium was found in mid-season although no larvae had been seen before then. The roughness of the plot tree and the considerable lichen growth presented many hiding places for such a small insect. This difficulty in detection, coupled with a lack of knowledge on the behavior of Leucopis, could have created a situation where an entire predator complex was overlooked.

Despite the poor results of the study in 1958, it is still believed that the above system of evaluation has merit. Evaluations in 1959 should improve -- primarily because of improved techniques and increased knowledge of the overall problem. Better tree selection alone should be a great help in reducing such problems as predator detection and the effects of varied environment between caged and non-caged plots. Information on how to select trees that will survive the summer has been furthered and should prevent duplication of the tree mortality problem experienced in 1958.

Probably the greatest value from the described method of evaluation will be in determining the effectiveness of predators that are active over short periods. With such species, predation would occur quickly and the effects of varied environment between caged and uncaged plots would be minimized. Insects, such as C. rita, that occur in low densities over extended periods, would be the most difficult to evaluate. Here, any method of evaluation used would need to detect effects of a slow accumulation of light predation, and at the same time eliminate effects due to differences in environment between caged and uncaged plots.

HOST TREE SUSCEPTIBILITY TO CHERMES

The following section describes observations made on host susceptibility to the balsam woolly aphid. It includes (1) a list of Abies found naturally infested with *Chermes piceae* in the Pacific Northwest, (2) the findings of a "gouting" study, and (3) some observations on the decline of chermes-infested subalpine fir.

True Firs Infested in the Pacific Northwest

Thirteen species of true fir were observed supporting at least light populations of *C. piceae* in 1957. One additional species, *Abies sakhalinensis* was found infested in 1958. The following list presents all the susceptible species observed to date in Oregon and Washington:

1. *Abies lasiocarpa* (Hook.) Nutt. -- subalpine fir
2. *A. fraseri* (Pursh.) -- Fraser fir
3. *A. amabilis* (Dougl.) Forbes -- Pacific silver fir
4. *A. grandis* (Dougl.) Lindl. -- Grand fir
5. *A. lasiocarpa* var. *arizonica* (Merr.) Lemm.--cork bark fir
6. *A. balsamea* (L.) Mill. -- balsam fir
7. *A. procera* Rehd. -- noble fir
8. *A. concolor* (Gord. & Glend.) Lindl. -- white fir
9. *A. alba* Mill. -- silver fir
10. *A. cephalonica* Loud. -- Greek fir
11. *A. pinsapo* Boiss -- Spanish fir
12. *A. sibirica* Ledeb. -- Siberian fir
13. *A. firma* Sieb. and Zucc. -- Momi fir
14. *A. sakhalinensis* (fr. Schm.) Mast. -- Sakhalin fir

The first eight species are arranged in order of decreasing damage by chermes. No detectable injury has been observed on the other six species. Basis for rating is confined entirely to the appearance of the trees rather than economic values.

Wind River Gouting Study

Observations on apparent susceptibility and nature of gouting were started in the Wind River Arboretum in 1957. In August of that year, new shoots on two infested subalpine fir were tagged. The number of developing buds on each shoot was recorded, and microscopic examinations were made periodically to determine the number and stages of chermes present. Seven of the shoots were chosen for repeat photography to show progress of gouting. Table 3 and figure 4 show the nature and appearance of damage on different dates from the beginning of observations until July of 1958.

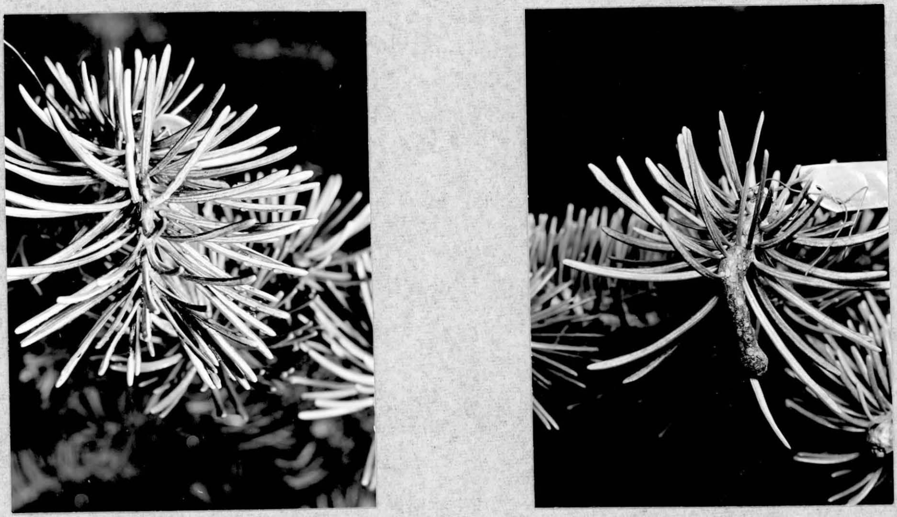
The increase in number of bud-infested chermids between the July and December examinations in 1957 was due to both trees having active bole infestations which were producing the insects migrating to the twigs. The decrease in bud populations in 1958 was partly due to natural mortality and partly to increasing damage to the host.

First indications of damage to current growth were already apparent by August 1957. Twig 447, as shown in figure 4a, exhibited a conspicuous downward crook. By March, 1958 the distal portion of the twig appeared to be dead and showed a severe rupture in the outer dermal layer. Bud flush occurred in April, and by May it became apparent that most of the infested twigs on the tree would not put out new growth. It appeared at the time that most of the damage was in the form of bud inhibition with a slight amount of needle loss distally. It was not realized until July that some of the buds were completely dead.

Table 3.--Relation of chermes numbers to gouting on subalpine fir in Wind River Arboretum.

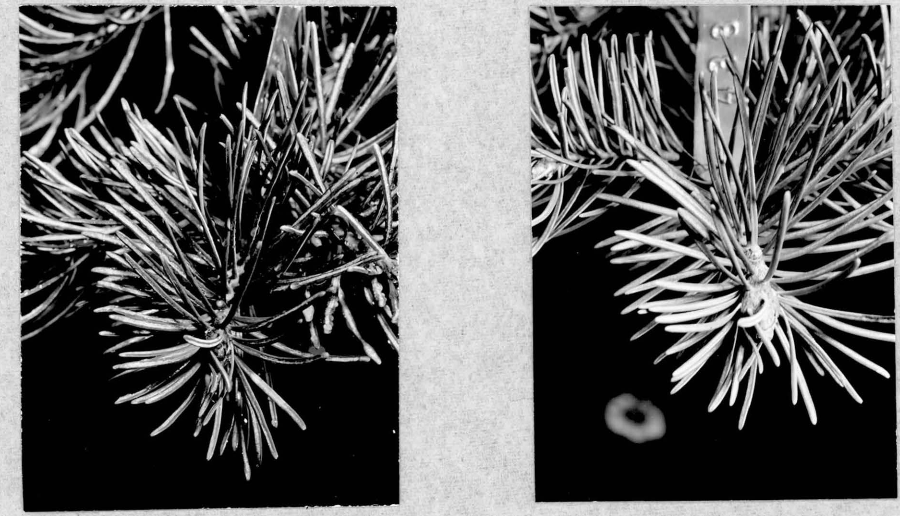
Twig no.	No. of developing buds	Chermes population on examination dates 8-16-57	12-21-57	3-8-58	5-9-58	7-11-58	Condition of twig on last date
437*	3	18 N	26 N	2N;61	0	0	Distal 1/2" of twig dead; needles gone.
438*	3	7 N	7 N	4N;41	1 A	4N;61	Bud inhibited but not killed; moderate swelling.
439	2	29 N	33 N	3N;81	2 A	0	Last 1/2" of twig dead; living portion lumpy.
440	1	10 N	34 N	6 I	3 A	4N;2A	Buds inhibited but not killed; slight swelling.
441*	1	13N;2 I 2 A	12 N	6N;14I	5 A	0	Complete kill of twig; no gouting.
442	1	7N;1I; 1A	-	6 N	1 A	3N;2I	Buds inhibited and showing slight swelling and down-crook.
443	1	10 N	-	9 N	6 A	12N;3A	Buds inhibited but not killed
444	3	9 N	-	21N;2I	3 A	3N;2I	Buds inhibited and a definite terminal gout starting.
445	3	2 N	-	5 N	0	0	No damage; new shoot present.
446*	3	50 N	115 N	46N;40I	4 A	0	Distal 1/2" dead with large fissures in side; lumps on living portion.
447*	3	100N;2I	-	0	0	1 N	Distal 1" dead and with large fissure. Severe down crook.
448*	1	43N;2I	26 N	5N;13I	3 A	0	Distal 1/2" dead; living portion with conspicuous lumps.
449*	3	42N;1I	-	25N;1I	5 A	0	Buds appear dead; and all needles dropping.
450	1	7 N	29 N	23N;5I	3 A	0	Complete kill but does not appear to be from chermes.

Key: "N" - neosisten; "I" - intermediate (2nd and 3rd instar); and "A" - adult.
* - photos taken.



September, 1957 July, 1958

A.



September, 1957 July, 1958

B.

Figure 4.--Appearance of subalpine fir buds in July 1958 following attack by Chermes in late 1957.

A - Twig 447. Severe damage resulting from attack of more than 100 sistens. Note the downward crook, the dead terminal, and the swollen appearance of the living proximal area by 1958.

B - Twig 438. Appearance before and after attack by seven neosistentes. Little apparent damage occurred, but bud was inhibited and no new growth occurred in 1958.

The best correlation of insect density to twig damage appears to be with the population recorded on August 1957 -- a time when plant processes are still quite active. Twig 445 shows that subalpine fir can support two sistentes during the active period and still produce new growth. Populations of 7 to 10 sistentes, as revealed by twigs 438,440, 442, 443, and 444, will result in bud inhibition (figure 4b). Populations of 17 sistentes and over will result in complete kill in the distal portion of the twig. The larger the population the more severe the kill. A high population on twig 447 resulted in a full inch of the twig being killed while the effects of lesser numbers was about one-half inch kill. Twigs having populations of 50 or more sistens are apt to be severely ruptured.

There was a notable difference in the amount of damage caused by first and second generation sistentes. First generation progeny settling on the succulent new growth cause much more damage than those attacking later in the year from subsequent generations. Several cases were noted where sistentes settled on the twigs in June and were causing visible abnormalities by early July. One case in particular was noted. A terminal twig was starting a downward crook with only three sistentes in the vicinity. Farther back on the twig a conspicuous swelling was observed in an area surrounding one sisten. Fortunately, the tendency is for sistentes of the first generation to settle on the old growth and sistentes of the second generation to settle on the new growth.

It was surprising to find that twigs were killed in one year, before significant gouting had occurred. Apparently much of what previously had been considered as hypertrophy, or gouting by chermes, was merely normal radial growth made more conspicuous by bud inhibition in one part of the twig and necrosis and downward crook in another. This condition was especially evident in twig 447. There the distal one inch was dead while the proximal portion was still alive and putting on normal radial growth. The result was that the diameter of the living portion appeared out of proportion to the rest of the twig. At the extreme end there was a small lump which might have been called a small gout. Actually it was the killed bud which was larger than the rest of the twig in the beginning.

About the only real indications of true hypertrophy noticed were the small lumps on the proximal portion of the new shoots and the swelling of the annual limb nodes. Both cases seemed to be aggravated by fast growth of the host. Those sistentes that settled in the spring when growth was most rapid caused much more swelling than those settling in late summer.

The results of this study were not especially encouraging from the standpoint of whether insect predators can be used to prevent gouting. It appears that the damage is done by the neosistentes that settle down during the growing season and that injury will result regardless of whether or not they develop further. Even if destroying the intermediate and adult stages would allow normal bud development, few known predators have the searching ability to locate and destroy twig-inhabiting populations. It becomes increasingly apparent that, on trees where only crown infestations exist, the balsam woolly aphid is its own worst enemy -- attacks in large numbers only succeed in killing a large portion of the favored food supply, i.e., the new growth.

The study on host susceptibility was expanded this year to include other host species. Observations are now being made on:

1. Pacific silver fir
2. Cork-bark fir
3. Shasta red fir
4. California red fir
5. Noble fir
6. Grand fir
7. Fraser fir
8. Sakhalin fir
9. Korean fir

In contrast to the naturally infested subalpine fir studied since 1957, these host species were artificially infested by tying pieces of infested bark to the twigs. In some cases cotton was wrapped around the twig to get a larger population to settle. On grand fir, sistentes could not be made to settle in any other way. When cotton was present, the great majority of sistentes settled under it and back from the bud. When a free choice was allowed by excluding cotton, the greatest number congregated on the bud.

Symptoms of Imminent Tree Mortality in Subalpine Fir

In 1958, symptoms of impending tree mortality in subalpine fir were followed rather closely on the predator evaluation tree at Willamette Pass. In the spring the most noticeable feature about the tree was the ragged, sparse appearance of the crown. Another symptom was that the bark of the upper portion of the infested bole had a blackish cast. This appearance was caused by internal "bleeding" just under the outer bark layer. As the season progressed, the blackened zone gradually moved down the stem, and by late July it had almost reached ground level. For some unknown reason the newly hatched crawlers preferred to concentrate and settle on the afflicted bark. Once settled, they failed to develop further. Consequently, there was a steady increase in the neosisten population on the darkening areas and a corresponding decrease in the number of adults. In the period from July 7 to August 8 the neosisten population climbed from an average of 67 per square inch to 176. On some plots more than 300 neosistentes were counted per square inch.

By mid-August it became apparent that the tree was going to die. The entire stem was almost black and dense groups of neosistentes were visible to the naked eye. The only living adults were those near the root collar. The foliage faded to a deep yellow but never became red. Subsequent observations on other infested subalpine firs revealed the same symptoms except that often they passed through the deep yellow stage to a brilliant red.

TREND PLOT STUDIES

Three trend plots of 100 trees each were established in 1954 in mature Pacific silver fir in southwest Washington. Study objectives and the methods and procedures of plot establishment and evaluation are outlined in the 1957 progress report. No changes have been made since that time.

All trees were alive when first tagged and since then only four have died. Annual examinations since 1956 have shown increasing recovery of the trees (Figure 5). This year's data, however, shows only slight change over that recorded in 1957. Tables 4 and 5 summarize the information recorded on the three plots in 1958.

Table 4.--Condition summary of Pacific silver fir on trend plots in 1958.

		Plot 5	Plot 6[1]	Plot 7	Total or average
Total Number of Trees by Crown Class:					
DOMINANT		31	7	48	86
CODOMINANT		41	48	30	119
INTERMEDIATE		24	38	22	84
SUPPRESSED		4	1	0	5
Total		100	94	100	294
Total Number of Trees Dead and Seriously Weakened by Crown Class:					
DOMINANT		10	2	13	25
CODOMINANT		6	1	6	13
INTERMEDIATE		1	0	2	3
SUPPRESSED		1	0	0	1
Percent of Trees Dead and Seriously Weakened by Crown Classes:					
DOMINANT		32.3	28.6	27.1	29.1
CODOMINANT		14.6	2.0	20.0	10.8
INTERMEDIATE		4.2	0.0	9.1	3.6
SUPPRESSED		25.0	0.0	0.0	20.0
Average DBH of All Trees:		20.0	18.6	23.6	20.7
Average DBH of All Trees Dead and Seriously Weakened:	1956	23.6	23.8	27.4	24.8
	1957	22.4	27.0	26.5	25.4
	1958	24.7	32.7	27.0	26.4
Average Numerical Condition of Trees by Crown Class:[2]					
DOMINANT	1954[3]	1.6	1.3	1.3	1.4
	1956	2.1	2.3	2.3	2.2
	1957	1.6	2.0	1.8	1.8
	1958	1.7	2.0	1.7	1.8
CODOMINANT	1954	1.2	1.0	1.2	1.2
	1956	1.5	1.7	1.9	1.7
	1957	0.9	1.1	1.6	1.2
	1958	1.0	0.9	1.4	1.0
INTERMEDIATE	1954	1.1	0.9	1.1	1.2
	1956	1.1	0.9	1.6	1.6
	1957	0.5	0.2	0.8	1.0
	1958	0.5	0.3	1.0	0.5
SUPPRESSED	1954	1.0	2.0	-	1.2
	1956	1.2	2.0	-	1.6
	1957	1.0	1.0	-	1.0
	1958	0.8	0.0	-	0.6
Total Average Numerical Condition:	1954	1.28	0.98	1.23	1.16
	1956	1.56	1.37	2.03	1.66
	1957	1.03	0.82	1.55	1.14
	1958	1.07	0.69	1.55	1.11

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[1] Six trees lost to windthrow.

[2] Key: 0, Full vigor; 1, Slightly weakened; 2, Moderately weakened; 3, Seriously weakened; 4, Dead.

[3] Initial rating.

Table 5.--Decline and recovery of plot trees by 1958 - expressed as a percentage of the total number of trees in the damage class in 1954.

Original crown condition	No change	Decline 1 class	Decline 2 classes	Decline 3 classes	Recover 1 class	Recover 2 classes
	Percent	Percent	Percent	Percent	Percent	Percent
Full vigor	70.4	25.9	0	3.7	-	-
Slightly weakened	34.1	17.8	6.7	0.5	40.9	-
Moderately weakened	32.6	32.6	2.3	-	20.9	11.6
Seriously weakened	50.0	18.8	-	-	25.0	6.2
All trees	38.1	20.7	5.1	0.7	33.3	2.1

Analysis of data shows that the largest trees in the stand have suffered the greatest damage. They are also the slowest to recover. Trees in the dominant crown class account for only 26 percent of the total number of plot trees, yet in 1956 and 1957, 55 percent of the dead and seriously weakened trees occurred in that class. In 1958 there was a decrease in the total number of trees dead and seriously weakened, although the percentage of dominant trees falling in those two damage classes increased to almost 60 percent of the total. It is also noted that while the stands have shown considerable recovery the past two years, the average diameter of trees dead and seriously weakened has progressively increased. Plot 7, the stand with the largest average tree diameter, continued to exhibit the greatest damage and the least recovery. Conversely, plot 6, which has the smallest average stem diameter, showed the least damage and exhibited the greatest amount of recovery.

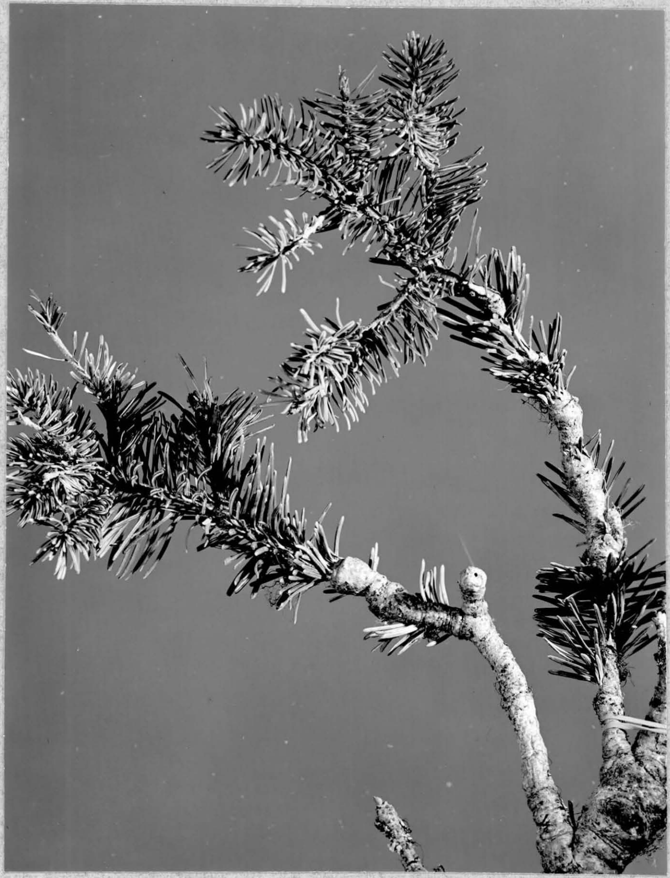

Figure 5.--Silver fir branch showing recovery from gout.

For the past five years plot analyses have been based on five overall tree condition ratings, varying from full vigor to dead (See key following table 4). Additional detailed information has also been taken on the tree characters used in arriving at the condition ratings. These data have not been reported to date because the yearly changes in stand conditions were large enough to be shown by the overall ratings. However, summaries of the 1958 data indicate that a more detailed analysis should be made. This became apparent when the obviously improved tree conditions on the plots were not reflected in the overall tree condition ratings. A more sensitive analysis, using all data collected since 1954 is planned in the near future.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that studies in 1959 on the biology and control of the balsam woolly aphid proceed in much the same areas of investigation as in 1958. Major emphasis should be placed on (1) the identification of the various life stages of the known native predators, (2) the introduction of foreign predators, (3) the study of the biology and behavior of native and established foreign predators, and (4) the evaluation of effectiveness of native and established foreign predators. No new studies are recommended.